S P E C I F I C A T I O N

TITLE

OPTICAL DATA READER WITH CONTROL MECHANISM
IMPLEMENTED BEHIND THE WINDOW

5   BACKGROUND OF THE INVENTION

The field of the present invention relates to optical
data readers such as barcode readers. More particularly,
the field of the present invention relates to the
controlling of optical data readers in response to certain
10 external conditions.

Many conventional optical data readers incorporate
circuitry to switch the reader into an inactive or "sleep"
mode when the reader is not used for a predetermined time
(e.g., one minute). The sleep mode is typically used to
15 reduce power consumption, save energy, and reduce wear and
tear on moving components. In flying spot laser barcode
scanners, the laser is typically turned off when the
scanner is in the sleep mode. Turning the laser off also
promotes laser safety by minimizing the chances that the
20 eyes of an operator or a bystander will be exposed to an
excessive amount of laser light.

Systems that incorporate a sleep mode require a
mechanism to return a sleeping system to the operational
mode, i.e., to "wake up" the system. One conventional
25 prior art approach for implementing a wake-up function in a
barcode scanner is to use a passive photodetector, aimed
into the scanning volume of the scanner, to monitor changes
in ambient light, (arriving, e.g., from a ceiling light
fixture). When an object is moved into the scanning

volume, the shadow of the object will usually fall on the photodetector, thereby changing the amount of ambient light reaching the photodetector. The photodetector output will change in response to the changes in detected light. When

5   a change is detected (e.g., from low light to high light or vice versa), the system switches from sleep mode into the operational mode.

It can, however, be difficult to implement an ambient light detecting system that will reliably wake a data

10   reader up from the sleep state every time an object is passed in the vicinity of the data reader. This is due in part to the wide variety of environments in which the data readers are used, ranging from dimly lit to brightly lit environments.

15   Because of the difficulty of implementing a wake-up function based solely on detected variations of ambient light, some prior art systems incorporate a manually operated pushbutton wake-up switch. The pushbutton switch is used by the operator to wake up the system whenever the

20   automatic wakeup system fails to operate properly. In some of these prior art systems, the pushbutton switch is also used to control the volume of the read-acknowledgement beeps that are generated after a barcode is successfully read.

25   Unfortunately, a significant number of additional assembly steps are needed to implement a backup wake-up function using a mechanical pushbutton switch. These include, for example, punching a hole in the data reader

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chassis, mounting the switch into the hole, providing a
wiring harness to connect with the switch, and making the
connection between the switch and the harness. When the
data reader is used in environments where contamination is

5   possible (e.g., in a supermarket checkout scanner, where
spills may occasionally occur), special care must be taken
to protect the switch from contamination. These steps may
further increase the component cost and the cost of
assembly. Due in part to these disadvantages, the

10   inventors have recognized a need for a reliable wake-up
system and/or function control system that does not rely on
an independently mounted mechanical switch.

Safety is another important considerations in optical
data readers. In particular, with laser-based barcode

15   scanners, it is desirable to minimize exposure to laser
light.

One specific situation where undesired exposure to
laser light can occur is when the window in a console-
mounted barcode scanner is removed for servicing (e.g., to

20   replace a scratched window). A current approach for
minimizing this risk involves providing two windows: an
inner window and an outer window. With this double window
configuration, the outer window can be replaced without
exposing the laser source, because the inner window remains

25   in its position while the outer window is being replaced.
The double window configuration, however, increases the
component count, the weight, and the cost of the resulting
system, and complicates the manufacturing process. Due in
part to these disadvantages, the inventors have recognized

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a need to reduce the risk of laser light exposure without relying on a double window configuration.

SUMMARY OF THE INVENTION

The present invention in one aspect provides a method and apparatus for controlling an optical data reader based on detected reflections from a light source.

In a preferred embodiment as described herein, control of a data reader is accomplished by illuminating an object located in front of a window with a light source, and detecting the light from the light source that has been reflected by the object. The amount of detected light is compared to an expected amount to determine when an object is present in front of the window, and a data reader control function is initiated in response to the determination. Optionally, the proximity of an object may be determined based on the detected light, and different control functions may be initiated depending on the proximity of the object.

In another preferred embodiment as described herein, control of a console-mounted data reader is accomplished by illuminating a console window with a light source, and detecting the light from the light source that has been reflected by the window. The amount of detected light is compared to an expected amount to determine whether the window is present. If the window is not present, the data reader is disabled. In a preferred variation of this embodiment, only a single console window is used in a console-mounted data reader.

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In yet another preferred embodiment as described herein, a data reader apparatus includes a light source and a light detector located behind a window. The light source is aimed to illuminate an object located in front of the

5 window, and the light detector is aimed to detect light from the light source that has been reflected by the object and/or the window. When the amount of detected light exceeds a certain level, an operation of the optical data reader is controlled.

10 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a block schematic diagram of a data reader in accordance with a first preferred embodiment as described herein.

FIG. 1B is a plan view of the FIG. 1A embodiment that

15 illustrates a preferred arrangement of components behind a window.

FIG. 2 is a block schematic diagram of a data reader in accordance with a second preferred embodiment as described herein.

20 FIG. 3 is a graph of a light detector output in the FIG. 2 embodiment.

FIG. 4A is a graph of brightness for a first example of a modulated light source output in the FIG. 2 embodiment.

FIG. 4B is a graph of brightness for a second example of a modulated light source output in the FIG. 2 embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5   FIG. 1A is a block diagram of a preferred data reader system 100 in accordance with one embodiment described herein. The data reader system 100 includes an optical data reader subsystem 170, which may comprise, for example, a flying spot laser barcode reader or a barcode reader with

10   an optical imaging system (e.g., based on a charge-coupled-device (CCD) photodetector). Examples of conventional flying-spot optical scanners can be found in U.S. Patent Nos. 5,007,691 (Bobba et al.) and 5,682,028 (Coleman), hereby incorporated by reference as if set forth fully

15   herein. In alternative embodiments, other types of optical data readers 170 (e.g., readers that recognize alphanumeric characters, other symbols or indicia, or even the overall appearance of an object) may be used.

      The optical data reader subsystem 170 includes a

20   photodetector 175 (e.g., a photodiode or a CCD) located behind a window 130, configured to receive an optical input 144 through the window 130. A light source 120 is located behind the window 130, aimed to illuminate objects 134 located in front of the window 130. Preferably, the light

25   source 120, the light detector 140, and the optical data reader 170 are all located behind a window 130 having a single pane (as illustrated in FIG. 1B). In alternative embodiments, these same elements may be located behind different panes of a multi-pane window. A light detector

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140 is preferably located behind the window 130, and is
aimed to receive light from the light source 120 that has
been reflected by objects 134 located in front of the
window 130. An output of the light detector 140 is

5   compared to a threshold voltage in comparator 161. The
output of the comparator 161 is provided to a control
interface 171 which controls certain aspects of the
operation of the optical data reader 170, as described
below.

10   The light source 120 may comprise an incandescent
lamp, a light emitting diode (LED) connected in series with
an appropriate current limiting resistor, or any other
suitable light generating device. Light 132 from the light
source 120 is aimed outwards through the window 130.

15   Preferably, the window 130 is made of a material (e.g.,
glass or plastic) that is optically transparent at the
relevant frequencies, allowing most of the light 132 to
pass through the window 130. When no objects are present
in the vicinity of the window 130, the light 132

20   transmitted through the window 130 will continue outward
and will not be reflected back through the window 130. On
the other hand, when an object 134 is present in the
vicinity of the window 130, the light 132 emitted by the
light source 120 will reflect off the object 134 and return

25   through the window 130. The reflected light 136 will then
arrive at the light detector 140.

The light detector 140 generates an electrical signal
in response to the incoming light 136 that has been
reflected from the object 134. The light detector 140 may

be implemented, for example, using a light detecting

element (e.g., a photodiode) connected to a suitable

amplifier in a conventional manner. The light detector 140

generates an output signal that is related to the amount of

5   incoming light. For example, when a photodiode is used

together with a transimpedance amplifier, the amplifier

will have an output voltage that is proportional to the

amount of light arriving at the photodiode. When other

types of light detecting elements are used (e.g., a CdS or

10   Si photocell), appropriate changes to the amplifier should

be implemented, as well understood by those skilled in the

art.

When there is no ambient light, the entire output of

the light detector 140 is attributable to the light that

15   originates in the light source 120 and is reflected by the

object 134. When no object is present in the vicinity of

the window 130, no light is reflected back to the light

detector 140. When a reflective object 134 is introduced

in the vicinity of the window 130, the light from the light

20   source 120 reflects off the object 134, returns through the

window 130, and is detected by the light detector 140.

Generally, more light will arrive at the light detector 140

for objects that are closer, and less light will arrive at

the light detector 140 for objects that are farther away

25   (assuming the same reflectivity between objects 134).

The light detector 140 generates an output in response

to the intensity of the arriving light 136. When no light

arrives at the light detector 140, the output of the light

detector 140 will be relatively small. When an object 134

is introduced in the vicinity of the window 130, the output will take on a value that depends in part on the proximity and size of the object 134 -- it will be smaller for distant objects, and larger for nearby objects. In one

5 embodiment, this effect is used to detect the presence and proximity of objects in the vicinity of the window 130 by using comparator 161 to compare the output of the light detector 140 to a predetermined threshold voltage. When the object 134 is sufficiently close to the window 130, the

10 output of the light detector 140 will normally exceed the threshold voltage, and the output of the comparator 161 will be asserted (switching to a "high" state in the illustrated embodiment). Conversely, when the object 134 is not sufficiently close to the window 130, the output of

15 the light detector 140 will not exceed the threshold voltage, and the output of the comparator 161 will not be asserted (and will remain in a "low" state in the illustrated embodiment).

In alternative embodiments, the illustrated analog

20 comparators may be replaced with an analog-to-digital converter followed by a digital comparator (not shown), as will be appreciated by persons skilled in the art. The digital comparator may optionally be implemented in hardware or in software. The threshold voltage may be

25 generated in any suitable manner including, for example, dividing a supply voltage in a resistive divider 165, 166, or using voltage reference diode or IC (not shown). The particular level to which the threshold is set will depend on the function being implemented, as explained in more

detail below. In embodiments that use a digital
comparator, the threshold may be set by providing the
desired digital threshold to the comparator, or by setting
a desired threshold in software.

5   The output of the comparator 161 is provided to the
control interface 171 of the optical data reader 170. The
control interface 171 is configured to initiate a control
function when the output of the comparator 161 is asserted.

For example, the illustrated arrangement may be used
10   to implement a volume control function that is actuated
when an operator places his hand (or another object) in
front of an "active region" 131 (shown in FIG. 1B) of the
window 130 in the immediate vicinity of the light source
120 and light detector 140 (e.g., right up against the
15   window 130, or within an inch of the window). Preferably,
the active region 131 is marked in a suitable manner way on
the outer face of the window 130. Because actuation is
desired only when the operator's hand (or other object) is
very close to the active region 131 of the window 130, a
20   relatively high threshold should be selected to implement
this control function. With a high threshold, objects at
distant and intermediate distances will not reflect
sufficient light onto the light detector 140 to exceed the
threshold, and only objects in the immediate vicinity of
25   the active region will reflect sufficient light to exceed
the threshold.

When the threshold is exceeded, the output of the
comparator 161 will be asserted. The control interface 171

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recognizes the assertion of the comparator's output, and generates appropriate commands for the optical data reader to implement the desired volume control function, using any suitable technique. For example, the control interface may

5   write a control byte to a volume control register, or adjust a control voltage provided to a voltage-controlled oscillator. Optionally, the control interface may be configured to wait for a predetermined dwell time (e.g. one second) before generating the commands, so that the control

10   function is not initiated by objects being moved across the window.

      In another example, the illustrated embodiment may be used to implement a wake-up function that is actuated when an object 134 is introduced in front of the window 130 in

15   the general vicinity of the light source 120 and light detector 140 (e.g., less than about a foot away from the window). For implementing a wake-up function, a threshold should be selected so that the reflected light 136 received from very distant objects 134 does not cause the output of

20   the light detector 140 to exceed the threshold, while the reflected light 136 received from objects 134 in the general vicinity of the window 130 causes the output of the light detector 140 to exceed the threshold. When the threshold is exceeded, the comparator 161 asserts its

25   output. The control interface 171 recognizes the assertion of the comparator's output, and generates appropriate commands for the optical data reader to implement the desired wake-up function, using any suitable technique

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(e.g., by switching on the power to the laser source and
enabling motion of the scanning mirror).

FIG. 2 is a schematic block diagram of another
preferred data reader system 200, which is similar to the
5   FIG. 1A-1B embodiment, but incorporates a number of
additional features. The data reader system 200 includes
an optical data reader subsystem 270 including a
photodetector 275 located behind a window 230, configured
to received its optical input 244 through the window 230.
10   A light source 220 is preferably positioned behind the
window 230, aimed to illuminate objects 234 located in
front of the window 230. A light detector 240 is located
behind the window 230, and is aimed to receive light from
the light source 220 that has been reflected by objects 234
15   located in front of the window 230. An output 248 of the
light detector 240 is compared to a set of thresholds
applied to comparators 261 through 263. The outputs of the
comparators 261 through 263 are provided to a control
interface 271, which controls certain aspects of the
20   operation of the optical data reader 270. An optional UART
272 receives an input from the light detector 240 via the
A/D converter 255, and controls the light source 220 via
the D/A converter 256.

As with the first embodiment, the light source 220
25   illuminates objects 234 in front of the window 230, and
light 236 reflects off those objects and is detected by the
light detector 240. In the FIG. 2 embodiment, however,
instead of comparing the output of the light detector 240
to a single threshold, a plurality of comparators 261

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through 263 are used to compare the output 248 of the light
detector 240 to a plurality of thresholds. In an
alternative embodiment, the illustrated analog comparators
may be replaced by a D/A converter followed by digital

5 comparator (not shown). The digital comparator may be
implemented in either hardware or software, as described
above in connection with the FIG. 1 embodiment.

The thresholds for the comparators 261-263 may be
generated, for example, by choosing series-connected

10 resistors 266 through 269 in a resistive divider network to
yield the desired threshold voltages at the negative
terminals of each of the comparators 261 through 263, or in
any other suitable manner. Alternative techniques for
generating multiple threshold levels may also be used,

15 including, for example, generating the thresholds in
software in embodiments that use digital comparators.

The comparators 261 through 263 then compare the
output 248 of the light detector 240 to each of the three
threshold levels simultaneously. In a preferred

20 embodiment, the threshold for comparator 261 is selected to
implement a user-actuated function control (e.g., a volume
control); the threshold associated for comparator 262 is
selected to implement a wake-up function; and the threshold
for comparator 263 is selected to implement a glass

25 detection function, as explained below.

Referring now to both FIGS. 2 and 3, when an object
234 is placed immediately in front of an "active region" of
the window 230 (i.e., in the immediate vicinity of light

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source 220 and the light detector 240), the amount of light received by the light detector 240 is generally very large (i.e., greater than level L3). The output 248 of the light detector 240 will be correspondingly large. A threshold

5   voltage TH3 that corresponds to the light level L3 is determined for the comparator 261 (e.g., during initial assembly, by measuring the detector output voltage when a test object 234 is placed one inch in front of the active region), and the determined threshold voltage is provided

10   to one input of the comparator 261. The output 248 of the light detector 240 is provided to the other input of the comparator 261.

        During operation, whenever an object 234 with sufficient reflectivity (e.g., a hand) is introduced

15   immediately in front of the active region, a large amount of light will hit the light detector 240, and the output 248 of the light detector 240 will be larger than the threshold TH3. When this occurs, the comparator 261 asserts its output. On the other hand, when no

20   sufficiently reflective object is located immediately in front of the active region, the output 248 of the light detector 240 will be smaller than the threshold TH3, and the comparator 261 will not assert its output. The control interface 271 recognizes when the output of the comparator

25   261 is asserted, and provides appropriate commands to the optical data reader to initiate the user actuated function control. This arrangement enables a user to initiate a function request by placing a hand (or another object) immediately in front of the active region of the window

230, or by otherwise masking the active region of the window 230.

When an object 234 is placed in the general vicinity of the window 230 active area, the amount of light received
5   by the light detector 240 will be greater than level L2, and the output 248 of the light detector 240 will be of corresponding size. A threshold voltage TH2 that corresponds to the light level L2 is determined for the comparator 262 (e.g., by measuring the detector output
10   voltage when a test object 234 is placed one foot in front of the active region), and the determined threshold voltage is provided to one input of the comparator 262. The output 248 of the light detector 240 is provided to the other input of the comparator 262.

15   Once the threshold voltage TH2 is established, whenever an object 234 is placed in the general vicinity of the window, an amount of light larger than level L2 will generally be received by the light detector 240, and the output 248 of the light detector 240 will be larger than
20   the threshold TH2. When this occurs, the comparator 262 asserts its output. On the other hand, when no object is present in the general vicinity of the active region, the output 248 of the light detector 240 will be smaller than the threshold TH2, and the comparator 262 will not assert
25   its output. The control interface 271 recognizes when the output of the comparator 262 is asserted, and generates appropriate commands to wake up the optical data reader (assuming that the reader is in the sleep mode). This arrangement enables the implementation of an automatic

wake-up command that is actuated whenever an object is passed in the general vicinity of the active region of the window.

5   When the window 230 is properly positioned in front of the optical reader 270, the light source 220, and the light detector 240, most of the light 232 from the light source 220 passes out through the window 230. A small portion of the light from the light source 220, however, is reflected by the window 230 back toward the light detector 240.

10   Preferably, the window 230 is not coated with a nonreflective coating. The level of the light arriving at the light detector 240 due to these reflections from the window 230 is set in advance to be slightly greater than level L1 in FIG. 3, which corresponds to a threshold

15   voltage TH1. As a result, as long as the window 230 is properly installed, the voltage at the output 248 of the light detector 240 should always be at least as large as TH1, and the output of the comparator 263 should always be asserted. In practice, the threshold TH1 should be

20   selected to be slightly lower than the voltage that corresponds exactly to L1, to compensate for tolerances in the circuit and for the case where the threshold TH1 is exactly equal to the output 248 of the light detector 240. The output of the comparator 263 is provided to the control

25   interface 271 of the optical data reader 270.

The detection of reflections from the above-described window effect can advantageously be used as a glass-absence detector, because the output of the comparator 263 only becomes unasserted when the output voltage of the light

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detector 240 drops below the threshold TH1 (which

ordinarily can only happen when the window 230 has been

removed from the system 200). When the control interface

271 recognizes that the output 248 of the comparator 263 is

5   not asserted, the control interface disables the optical

data reader. Preferably, the glass-absent condition is

latched by the control interface 271 to prevent the optical

data reader 270 from operating until the window 230 can be

replaced by a technician, so that reflections from external

10   objects will not re-enable the system. When the optical

data reader includes a laser (e.g., as in flying-spot laser

barcode readers), disabling the reader 270 preferably

includes turning off the laser.

Unless appropriate precautions are taken, ambient

15   light 238 arriving at the light detector 220 can be

misinterpreted as being light 236 that originated in the

light source 220 and was reflected by the object 234, which

could make the outputs of the comparators 261 through 263

unreliable. For example, if sufficient ambient light is

20   detected by the light detector 240, the output of the

comparator 262 would indicate that an object is present in

the vicinity of the window 230 when no object is actually

present. Ambient light can be particularly troublesome

when glass detection is implemented, because glass

25   detection requires the measurement of relatively low light

levels.

The effects of ambient light may be reduced

significantly by using a light source 220 that emits only

in a very narrow frequency band (e.g., a laser diode) in

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combination with a light detector 240 that only detects
light in the same frequency band (using, e.g., an optical
bandpass filter). But even if this combination is used,
the system 200 could still be adversely affected by ambient

5   light 238 that has strong components in the narrow
frequency band.

One approach to reject the effects of ambient light
238 (and thereby ensure that all of the light detected by
the light detector 240 originated from the light source

10   220) is to incorporate a modulator 226 into the light
source 220 and a matching discriminator 246 into the light
detector 240. In the illustrated embodiment, a light
emitting diode (LED) 222 is used as the light emitting
element in the light source 220. The LED 222 is driven by

15   an amplifier 224, which is controlled by a modulator 226.
The modulator 226 and amplifier 224 combine to generate a
driving waveform that modulates the brightness of the light
emitted by the LED 222.

A variety of modulation schemes may be used to

20   generate the driving waveform for modulating the brightness
of light emitted by the LED 222. For example, the
brightness of the emitted light may be controlled digitally
by switching power to the LED 222 on and off at a
predetermined frequency, as illustrated by waveform 410 in

25   FIG. 4A. Alternatively, analog control of the brightness
of the light emitted by the LED 222 may be implemented by
the modulator 226 and amplifier 224 by providing
appropriate driving signals to the LED 222 to produce a
brightness waveform 420, as illustrated in FIG. 4B. While

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modulation using numerous other waveforms may be used,
(e.g. triangle and ramp waves), the illustrated square wave
and sinusoids have the advantage of being relatively easy
to implement.

5   Returning now to FIG. 2, The modulated light 232
leaves the light detector 220 and travels outward through
the window 230. A portion of the modulated light 232 is
reflected back towards the light detector 240 (by either
the window 230 or objects 234), as described above.

10   Preferably, the light detector 240 comprises a
photodiode 242 connected to an amplifier 244 in a suitable
manner. For example, a current output obtained from the
photodiode 242 may be amplified by a transimpedance
amplifier to generate a voltage output that is proportional
15 to the magnitude of the light arriving at the photodiode
242. The output of the amplifier 244 will include a direct
current (DC) component that is attributable to the ambient
light (this component is DC because the ambient light does
not change rapidly). The output of the amplifier 244 will
20 also include a DC component that is attributable to the
modulated light from the light source 220 (i.e., the
average value of the modulated light), and an alternating
current (AC) component that is attributable only to the
modulated light from the light source 220.

25   Preferably, the light detector 240 also includes a
discriminator 246 that removes at least some of the
components of the arriving light signal that are not
attributable to the light source 220. The design of the

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discriminator 246 will depend on the particular scheme used
to modulate the light generated by the light source 220.
For example, if the light source is sinusoidally modulated,
as illustrated in FIG. 4B, the discriminator 246 may be

5   implemented using a DC blocking capacitor followed by a
band pass filter centered on the modulation frequency
(e.g., if the modulator 226 modulates at 12 kHz, the center
frequency of the band pass filter should also be 12 kHz).
A similar filter may also be used even when the light from

10   the light source 220 is modulated by a square wave, as
illustrated in FIG. 4A, because the fundamental frequency
component of the square wave 410 would be detected by the
band pass filter.

        Alternatively, other types of discriminators may be

15   used. For example, a demodulator tuned to the same
frequency as the modulator may be used to extract the
signal arriving at the photodiode 242. In another example
(not shown), when the light output of the light source 220
is modulated by a square wave, the discriminator 246 may be

20   implemented by sampling the received light at instants when
the light source is on, sampling the received light at
instants when the light source is off, and subtracting the
latter sample from the former. This approach works because
the first sample corresponds to the light received by the

25   photo diode 242 when illuminated by ambient light plus
light originating from the light source 220, and the second
sample corresponds to ambient light only (since the light
source 220 is instantaneously switched off). The amount of
light attributable to the light source 220 can therefore be

obtained by subtracting the ambient-only sample from the signal-plus-ambient sample. Preferably, both the modulator 226 and the sampling control in this embodiment (not shown) are synchronized by a suitable signal provided by the

5   modulator to the discriminator.

Optionally, much of the same hardware used to implement the functions described above may also be used to implement a wireless data link into the optical data reader 270. Such a data link may be used, for example, to set

10   system options such as a beep duration or a type of label to be read (e.g., UPC or EAN). It may also be used to initiate diagnostic functions from a remote handheld terminal with an IR interface (e.g., a Palm Pilot™ organizer, available from Palm, Inc.). The wireless data

15   interface may also be used to perform software upgrades for reprogrammable systems (e.g., where the system software is stored in flash memory), without connecting or disconnecting any cables to the scanning system 200.

The wireless data interface may be implemented by

20   using a UART 272 connected to the control interface 271 of the optical reader 270. For data transmissions, the serial output of the UART is provided to the modulator 226 via the D/A converter 256. Preferably, the modulator 226 modulates the light generated by the LED 222 in accordance with any

25   standard IR communication protocol such as Bluetooth™ or an Infrared Data Association (IrDA) protocol. Similarly, to implement data reception using the same photo detector 240 described above, the output of the amplifier 244 may be digitized by A/D converter 255, and the resulting digital

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data stream may be processed to extract serial data from incoming IR light signals, using any suitable technique.

The above described embodiments advantageously provide a simple and relatively inexpensive way to implement a
5   sleep mode wake-up function and to implement user control of a preselected function, without the drawbacks associated with an independent mechanical switch. In particular, because these functions are implemented optically, the detecting hardware may be built into a data reader module
10   located behind the window, thereby simplifying the assembly process. In addition, by using optical window detection, laser safety concerns can be addressed in a single-window system by turning the laser off when the window's absence is detected. As a result, the drawbacks associated with a
15   double window configuration can be eliminated. Optionally, a wireless data interface may be implemented in a manner that shares a significant portion of the hardware used to implement the light-level detection functions described above.

20   In one alternative embodiment, the glass-absence detection may be implemented by itself (i.e., without providing wake-up or function control features). The hardware configuration for such an embodiment would be similar to the FIG. 2 embodiment, but would use only one
25   comparator and one threshold voltage. In another alternative embodiment (not shown), digital comparators may be used instead of the analog comparators described above, or the comparators and their outputs may be implemented in software using a suitably programmed digital signal

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processor to implement level comparisons. Optionally, such processing may be integrated within the control interface 171, 271. Numerous other related embodiments will be readily envisioned by those skilled in the art.

5   While the present invention has been explained in the context of the preferred embodiments, it is to be understood that various changes may be made to those embodiments, and various equivalents may be substituted, without departing from the spirit or scope of the

10   invention, as will be apparent to persons skilled in the relevant arts.